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NEUTRAL ENVIRONMENT FOR SPACE STATION

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Abstract. The molecular number column densities along specific experiment lines-of-sight on the Space Station cross boom generally meet JSC 30426 requirements. The deposition of contaminants on payload surfaces exceeds the JSC 30426 requirements. These model predictions require updating because of the impact on background brightness predictions. An increase of a factor of 2 to 10 in column densities would result in an unacceptable optical background.

Introduction

The results presented in this brief position paper are a result of studies initiated by OSSA to determine the contamination compatibility of the cross boom and dual keel Space Station configurations with attached payloads. Details of this study are available in Space Station Contamination Assessment Summary, dated November 16, 1987.

Approach

The approach was to define the three-dimensional configuration of the Space Station and calculate surface-to-surface view factors and solid angles between surfaces and points in an extensive point matrix around the Space Station via a modified TRASYS model (Jensen and Goble, 1983).

Figure 1 shows the two levels of detail used for the geometry. One was a 145 node model for gas collision sources and interactions and the other a 350 node higher fidelity model for surface-to-surface deposition calculations.

The sources used for the operational period are shown in Table 2. In addition the RCS engines firing along z positioned at x = -750, y = $\pm$2000, and Z = -250 cm and the resistojet positioned at x = -3385, y = 0, and Z = -255 cm were included as sources for non-operational periods.

The surfaces of the modules and the service facility outgas at a rate of 6.1×10^{10} molecules $cm^{-2}\ s^{-1}$ (1×10^{-11} g $cm^{-2}\ s^{-1}$). The solar panels, thermal radiators, and power radiators outgas at a higher rate, 3.1×10^{12} molecules $cm^{-2}\ s^{-1}$ (5×10^{-10} g $cm^{-2}\ s^{-1}$). Outgassing molecules are considered to be emitted in a Lambertian distribution.

The criterion for leakage from Space Station modules is a total of 2,270 g day^{-1} (5 lb day^{-1}). This total leak rate was partitioned among the modules as follows. Seals were divided into three major categories according to increasing propensity for leakage: factory installed seals such as at fixed viewing ports (called "Inactive Seals Installed in Factory"), on-orbit installed seals such as those between modules and nodes that are not made and broken repeatedly (called "Inactive Seals Installed On-Orbit"), and active seals that are made and broken repeatedly on-orbit (called "Active Seals"). Inactive seals installed in factory were considered leakfree. Inactive seals installed on-orbit and active seals were represented by short cylinders or

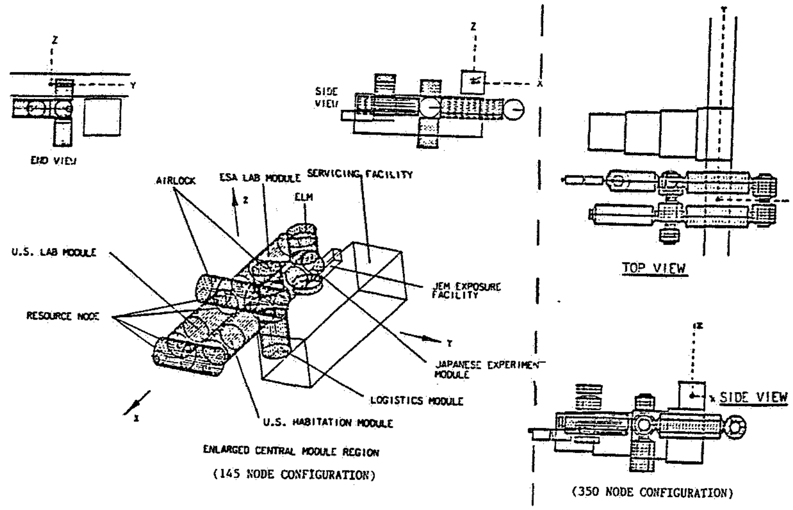


Fig. 1. Modeled configurations.

Table 1. Molecular Sources-Quiescent Period

SOURCE	TYPE	CONSTITUENTS	RATE
MODULE/SERVICE FACILITY SURFACES	OUTGASSING	MEAN MOL. WT. = 100	6.1×10^{10} MOLECULES/CM^2/SEC
SOLAR PANELS	OUTGASSING	MEAN MOL. WT. = 100	3.1×10^{12} MOLECULES/CM^2/SEC
THERMAL RADIATORS	OUTGASSING	MEAN MOL. WT. = 100	3.1×10^{12} MOLECULES/CM^2/SEC
POWER RADIATORS	OUTGASSING	MEAN MOL. WT. = 100	3.1×10^{12} MOLECULES/CM^2/SEC
INACTIVE SEALS INSTALLED ON ORBIT--TYPE 1 (RING)	LEAKAGE	75% N_2, 22% O_2, 2% H_2O, 1% CO_2	1.3×10^{15} MOLECULES/CM^2/SEC
INACTIVE SEALS INSTALLED ON ORBIT--TYPE 2 (RING)	LEAKAGE	75% N_2, 22% O_2, 2% H_2O, 1% CO_2	1.6×10^{15} MOLECULES/CM^2/SEC
INACTIVE SEALS INSTALLED ON ORBIT--TYPE 3 (RING)	LEAKAGE 2270 GM/DAY (5 LB_M/DAY) TOTAL	75% N_2, 22% O_2, 2% H_2O, 1% CO_2	1.7×10^{15} MOLECULES/CM^2/SEC
ACTIVE SEAL (RING)	LEAKAGE	75% N_2, 22% O_2, 2% H_2O, 1% CO_2	4.0×10^{15} MOLECULES/CM^2/SEC
AIR LOCK (DISK)	LEAKAGE	75% N_2, 22% O_2, 2% H_2O, 1% CO_2	3.6×10^{14} MOLECULES/CM^2/SEC
DOCKING RING (DISK)	LEAKAGE	75% N_2, 22% O_2, 2% H_2O, 1% CO_2	4.8×10^{15} MOLECULES/CM^2/SEC
VENT (LOCATED AT X=0, Y=-325 CM, Z=-831 CM, POINTING IN -Y DIRECTION)	VENT 0.1 GM/SEC	75% N_2, 22% O_2, 2% H_2O, 1% CO_2	1.0×10^{21} MOLECULES/SEC

"rings" in the Space Station model. "Type 1" (three seals) and "Type 2" rings (eight seals) were assigned a leak rate of 1.3×10^{15} and 1.6×10^{15}

molecules cm^{-2} s^{-1}, respectively (see Table 2), corresponding to a flow rate of 90.7 g day^{-1} (0.2 lb day^{-1}) for each seal. The difference in molecular flux for type 1 and type 2 rings was a result of different surface areas of the rings. "Type 3" rings (two seals) were assigned a leak rate of 1.7×10^{15} molecules cm^{-2} s^{-1}, corresponding to a flow rate of 75.7 g day^{-1} (0.167 lb day^{-1}) each. One active seal was considered at the attachment of the logistics module. This major ring source was assigned a leak rate of 4.0×10^{15} molecules cm^{-2} s^{-1}, corresponding to a flow rate of 227 g day^{-1} (0.5 lb day^{-1}). The remaining major leakage sources, the air locks and docking rings, were also assigned a leak rate corresponding to a flow rate of 227 g day^{-1} (0.5 lb day^{-1}). The specific molecular leak rates depended on the area of the sources, which in these cases were disks (see table). Leakage is considered to be emitted in a Lambertian distribution.

The vent passed an average flow rate of half the total average rate of 0.1 g s^{-1}. The other half was passed through an identical vent facing in the +y direction in order to give zero net thrust. The latter vent was not included in the model since it was entirely shadowed from the region of interest (above the modules). The vent was considered as a point source producing a density distribution given by

$$N(\text{molecules cm}^{-3}) = 5.7 \times 10^{15} \cos^2 (0.94\ \theta)/r^2$$

where r is the distance in cm from the source and θ is the angle from plume centerline.

Results

Cross Boom

Densities of the molecular sources were calculated at every point around the Space Station and the type of molecule and its source were tracked. A total of 30 different molecules or source state of the molecules was used. These included ambient, surface reemitted ambient, outgassing, leakage, and vent plus the scattered component of each of these.

Lines-of-sight were calculated at three positions along the boom. One position was at the center of the boom and the others 15 meters from the center. At the boom center the total number column density ranged from 2.4×10^{12} to 9.6×10^{11} molecules cm^{-2}. By species the surface reemitted atomic oxygen ranged from 7.7×10^{11} to 4.5×10^{11} atoms cm^{-2}, the surface reemitted N_2 ranged from 1.2×10^{12} to 2.3×10^{11} molecules cm^{-2}, O_2 ranged from 3.4×10^{11} to 3.9×10^{10} molecules cm^{-2}, and H_2O ranged from 7.3×10^{10} to 2.7×10^{9} molecules cm^{-2}. At y = 15 meters from the center the total density ranged from 4.7×10^{12} to 9.0×10^{11} molecules cm^{-2}. Water was the only species that exceeded requirements at a level of 7.5×10^{11} molecules cm^{-2} for one line-of-sight. The results for y = -15 meters ranged from 6.5×10^{12} to 1.1×10^{12} molecules cm^{-2} for total number column densities. Water reached a peak of 7.3×10^{11} molecules cm^{-2} for one line-of-sight. These results are summarized in Figure 2.

Direct flux deposition levels on surfaces at the three points along the cross boom reached rates of 5×10^{-12} to 1.8×10^{-11} g cm^{-2} s^{-1} and depended on solar array position. These values were for a flat surface facing forward, aft, left/right and upward along Z. For surfaces with a limited

	TOTAL NCD RANGE MOLECULES/CM^2	O ATOMS/CM^2	N_2 MOLECULES/CM^2	O_2 MOLECULES/CM^2	H_2O MOLECULES/CM^2
BOOM CENTER Y=0	2.4X10^{12} TO 9.6X10^{11}	7.7X10^{11} TO 4.5X10^{11}	1.2X10^{12} TO 2.3X10^{11}	3.4X10^{11} TO 3.9X10^{10}	7.3X10^{10} 2.7X40^{9}
Y=15M	4.6X19^{12} TO 9.0X10^{11}	-	-	-	UP TO 7.5X10^{11}
Y=-15M	6.5X10^{12} TO 1.1X10^{12}				UP TO 7.3X10^{11}

*DURING NONOPERATIONAL PERIODS THE COLUMN DENSITIES RANGED FROM 5.6X10^{12} TO 5.6X10^{15} MOLECULES/CM^2

Fig. 2. Number columnm density ranges cross boom - quiescent period.

	DEPOSITION GM/CM^2/S
o DIRECT FLUX - CROSS BOOM - DUAL KEEL	5X10^{-12} 3.0X10^{-14} 2.2X10^{-12}
o RETURN FLUX - CROSS BOOM	2.8X10^{-14} 2.3X10^{-13}

Fig. 3. Deposition ranges at payload positions on flat surfaces.

field-of-view the direct flux did not deposit. The return flux of contaminants via scattering interaction with the ambient ranged from 2.3 x 10^{-13} to 2.8 x 10^{-14} g cm^{-2} s^{-1} on flat surfaces. Limited fields-of-view of 0.1 steradians only received significant deposition when viewing along the direction of motion. These levels on the +x facing surfaces ranged from 1.2 x 10^{-12} to 3.9 x 10^{-13} g cm^{-2} s^{-1}. The deposition results are summarized in Figure 4.

Dual Keel

The number column densities for the dual keel lines-of-sight were 1 to 2 orders of magnitude less than the cross boom and should be acceptable for payload viewing.

The direct flux deposition levels on flat surfaces at the three points along the keel ranged from 2.2 x 10^{-12} to 3.0 x 10^{-14} g cm^{-2} s^{-1}.

Non-Operational Periods

The RCS engines firing along the +Z axis (upward) were evaluated for contributions to number column densities along the cross boom. The water content ranged from 5.6 x 10^{15} to 2 x 10^{13} molecules cm^{-2}. Since the effluent of the engines is H_2O it clearly replaced the other sources as the predominant contaminant. The resistojet with only one jet operating produced number column densities of water that ranged from 5 x 10^{13} to 1 x 10^{11} molecules cm^{-2} for H_2O. Multiple resistojets would cause the same increase in the column densities.

Figures 4, 5, and 6 show the types of graphic data that are presented in "Space Station Contamination Assessment Summary." Figure 4 shows the iso density contours in the X-Z plane. The numbers on the contours correspond to multiples of the ambient density which was 1.3 x 10^8 molecule cm^{-3} for this study. Figure 5 shows lines-of-sight integrated for the contour shown in Figure 4. Figure 6 is the same as Figure 5 except that the densities at each

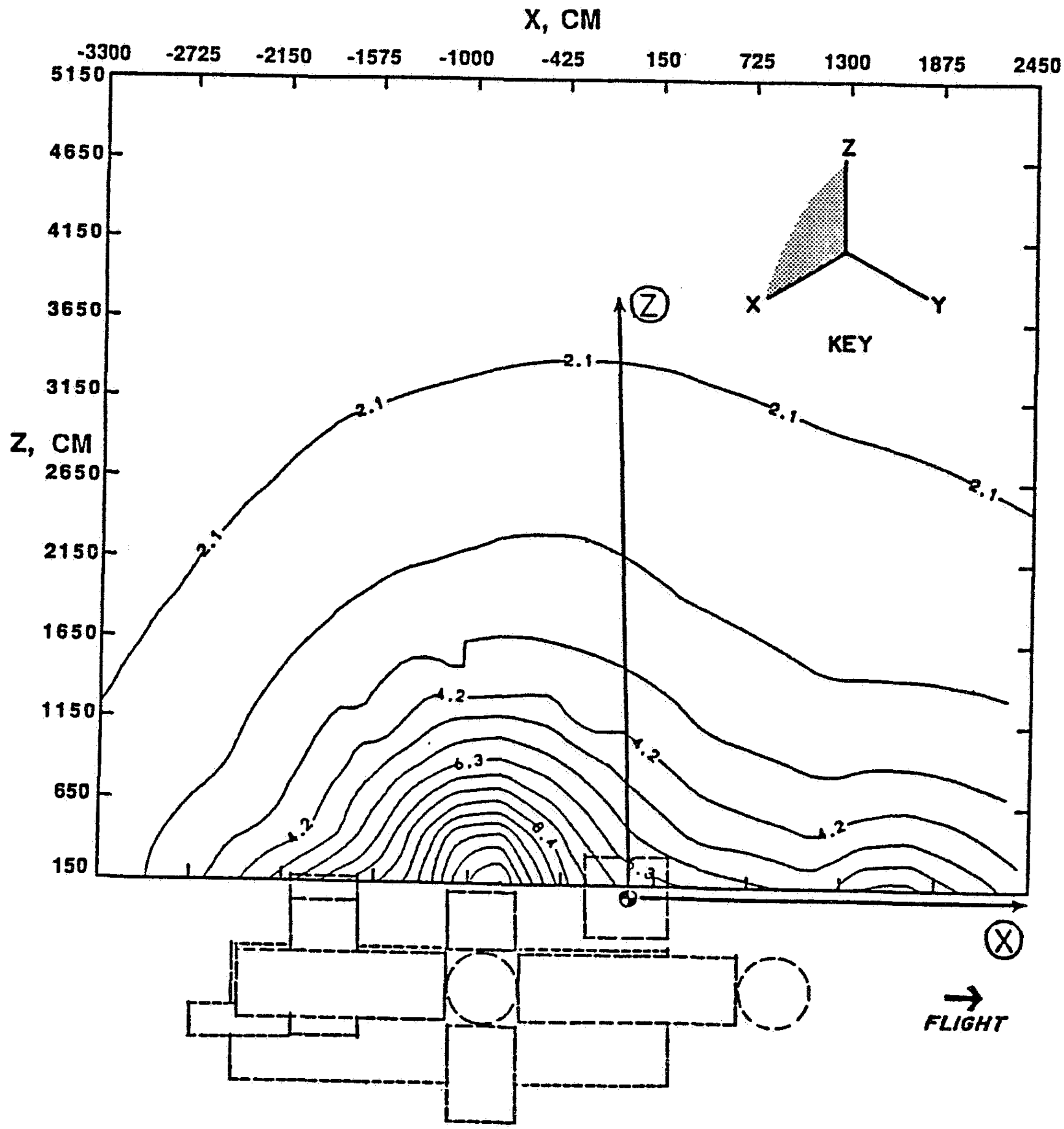


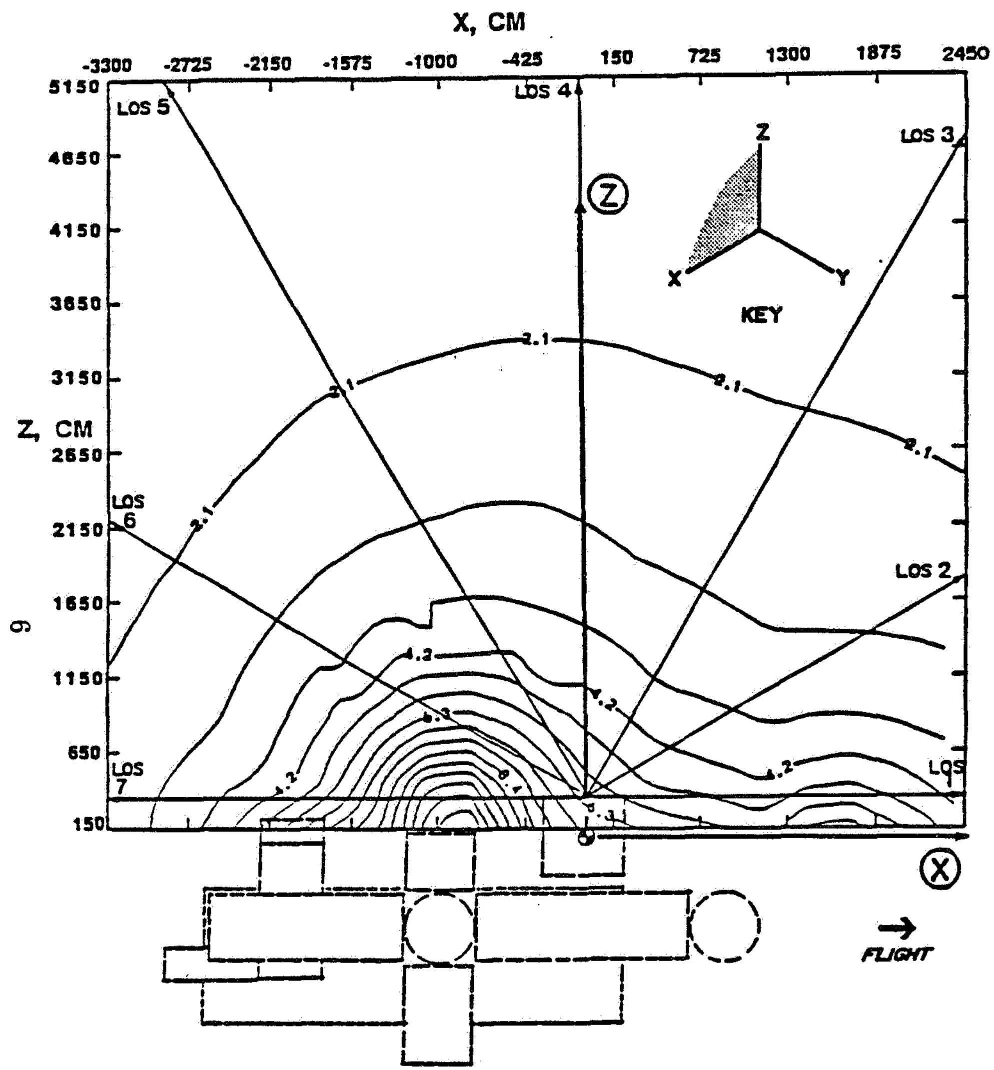
Fig. 4. Total density in X-Z plane at Y = 0.

point in the plane are shown so that users of the data can perform their own integration or use the densities directly for plasma analysis. The numbers are multiples of the ambient density.

Conclusions

Based on the assumptions for the sources only a few lines-of-sight on the cross boom exceed the JSC 30426 number column density requirements. It is not clear if these meet the zodiacal background requirements also in JSC 30426.

The dual keel configuration meets all column density requirements. For the dual keel the major contamination problems will result from the attached payloads creating local contaminant conditions that may be unacceptable.



LOS	TOTAL NCD w/o FREESTREAM AMBIENT	SPECIES NCD w/o FREESTREAM AMBIENT
LOS 1	1.7E+12	0 – 5.7E+11 N2 – 8.1E+11 02 – 2.3E+11 H20 – 1.6E+10
LOS 2	1.4E+12	0 – 7.7E+11 N2 – 4.3E+11 02 – 1.1E+11 H20 – 7.5E+9
LOS 3	1.3E+12	0 – 6.3E+11 N2 – 4.4E+11 02 – 1.2E+11 H20 – 8.1E+9
LOS 4	1.4E+12	0 – 6.2E+11 N2 – 5.1E+11 02 – 1.4E+11 H20 – 9.4E+9
LOS 5	1.3E+12	0 – 5.5E+11 N2 – 4.9E+11 02 – 1.3E+11 H20 – 9.1E+9
LOS 6	1.3E+12	0 – 5.3E+11 N2 – 4.8E+11 02 – 1.3E+11 H20 – 9.1E+9
LOS 7	1.1E+12	0 – 4.5E+11 N2 – 3.9E+11 02 – 1.1E+11 H20 – 7.3E+9

ALL VALUES MEET REQUIREMENTS

Fig. 5. Total density in X-Z plane at Y = 0 and NCDs for coplanar lines-of-sight with origin at X = 0, Y = 0, Z = 250.

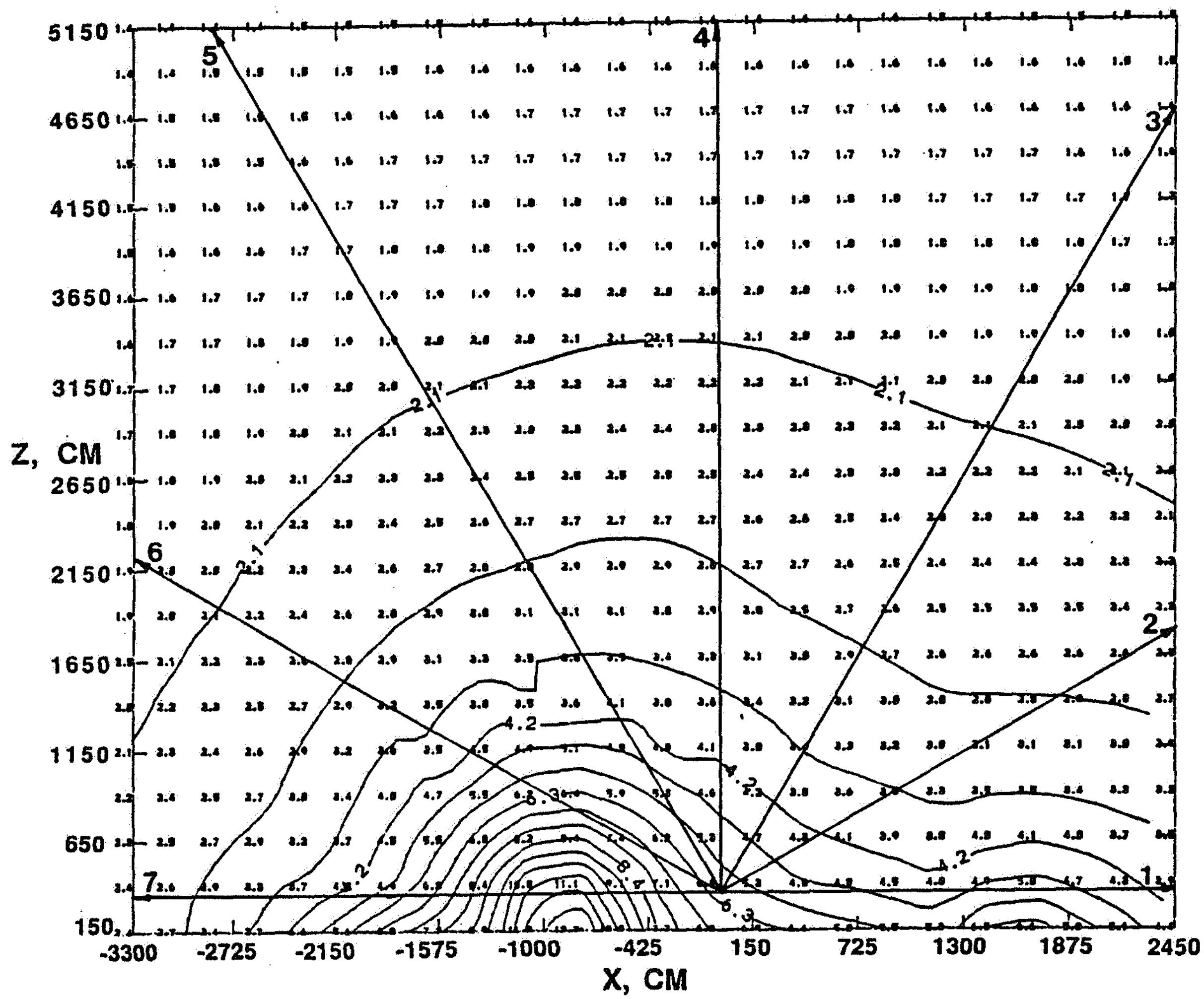


Fig. 6. Total density plot of Figure 5 with point values.

LOS	TOTAL NCD w/o FREESTREAM AMBIENT	SPECIES NCD w/o FREESTREAM AMBIENT
LOS 1	1.7E+12	O – 5.7E+11 N2 – 8.1E+11 O2 – 2.3E+11 H2O – 1.6E+10
LOS 2	1.4E+12	O – 7.7E+11 N2 – 4.3E+11 O2 – 1.1E+11 H2O – 7.5E+9
LOS 3	1.3E+12	O – 6.3E+11 N2 – 4.4E+11 O2 – 1.2E+11 H2O – 8.1E+9
LOS 4	1.4E+12	O – 6.2E+11 N2 – 5.1E+11 O2 – 1.4E+11 H2O – 9.4E+9
LOS 5	1.3E+12	O – 5.5E+11 N2 – 4.9E+11 O2 – 1.3E+11 H2O – 9.1E+9
LOS 6	1.3E+12	O – 5.3E+11 N2 – 4.8E+11 O2 – 1.3E+11 H2O – 9.1E+9
LOS 7	1.1E+12	O – 4.5E+11 N2 – 3.9E+11 O2 – 1.1E+11 H2O – 7.3E+9

Deposition levels on both the cross boom and the dual keel exceed the requirements on a flat surface at the payload positions. The dual keel levels are 1 to 2 orders of magnitude less than the cross boom. Limited field-of-view surfaces meet the deposition requirements except when viewing along the direction of motion.

The total leakage rate of 2270 gm day^{-1} (5 lb day) has not been demonstrated as an engineering feasibility. A change of a factor of 2 would cause more lines-of-sight to have column densities that exceed the criteria.

Any sources other than leakage and outgassing from the European and Japanese module have not been included.

The experiment volume pumpdown vent location used in this study minimizes its effluent impact on upper hemisphere viewing but does cause a potential problem for Earth pointing systems. This location has not been approved or shown to be the best location for engineering purposes. The flow rate used was an average during volume pumpdown. Higher values will occur initially. No gas emissions other than cabin air were analyzed.

Experiments with surfaces within 2 or 3 meters of each other must have outgassing rates less than 1×10^{-13} g cm^{-2} s^{-1} in order to meet the deposition requirements on nearby payloads.

The operation of the RCS engines and the resistojets creates number column densities that exceed requirements.

Recommendations

The following recommendations are made because of their potential impact on Space Station and the attached payloads.

1. Update Contamination Model/Perform Sensitivity Study
   Include Phase I extra solar arrays and remove service facility. Perform trades on collision cross section, scattering distribution, and surface emissions.

2. Experiment Vent Optimization
   Determine optimum vent location taking into account, engineering requirements, attached payload needs, venting needs, gases used, densities near solar panels, microgravity needs, etc.

3. Update JSC 30426 Requirements
   Based on spectral brightness versus column density upgrade requirements. Also, revisit other updates that may be required for deposition, particulates, etc.

4. International Module Sources
   Determine other contaminant sources that may exist from the European and Japanese modules. Input to the contamination model for evaluation.

5. Shuttle/Hermes Visits Docked
   Determine molecular deposition and particulate source impact of the Shuttle docked to the Space Station and for visits by the European Space plane (Hermes).

6. Update Outgassing Sources
   Determine levels of outgassing that may exist for sources or determine what is allowed based on analysis.

7. Spectral Brightness
Continue modeling by D.G. Torr, UAH, to allow brightness predictions to be incorporated into number column density predictions. Support this study with update neutral gas density predictions.

8. Flight Experiments
Flight experiments at several altitudes to measure spectral brightness emissions of known sources are required to obtain necessary excitation data for predictions. Also gas density/direction measurements are required at several altitudes to verify/update contamination model predictions.

9. Detection Sensors
A combination of sensors to verify the contaminant environment are required to be placed on the Space Station at multiple locations. These should be decided upon, built, flight tested, and finally packaged for Space Station.

10. Surface Effects
Determine the surface phenomena that exist for excitation of adsorbed species and their subsequent remission.

11. Payload to Payload Contamination
Model the payloads on the boom to see what column densities may exist for near neighbors and the deposition requirements for close proximity payloads.

12. Earth Pointing Requirements
Develop a set of contamination number column density and spectral background brightness requirements for Earth pointing systems. This may allow vent location to be better located for upper hemisphere viewing.

13. Model Verification Shuttle Data
Revisit Shuttle data that has not been reduced for correlation to contamination predictions. Include IECM, SPAS, IR measurements, and any other data that are useful.

Reference

Jensen, C.L., and Goble, R.G., Thermal Radiation Analysis System, MCR-73-105 (Rev. 5), June 1983.